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Polyhedral Computing and spatial research in architectural education

Applications to spatial research

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Synopsis

In this paper we investigate an innovative way for modelling complex combinatorial spatial structures, called *Polyhedral Computing*. Already confirmed as an efficient tool regarding spatial cognition and education, the proposed framework of Polyhedral Computing can become an appropriate instrument for contemporary spatial research in architecture, education and design. Therefore, within this framework we propose the use of an algebra that acts on a set of Archimedean polyhedra - called "*variables*" - and applies various "*connectivity operators*" to create geometric expressions that satisfy specific validation rules. The construction flow for such geometric expressions can be described as an evolutionary process within the wider domain of computational architecture.

"If you want to teach people a new way of thinking, don't bother trying to teach them. Instead, give them a tool, the use of which will lead to new ways of thinking."

Buckminster Fuller

Key words: Architecture, spatial cognition, polyhedra, computing, education.

1. Introduction

Spatial cognition becomes increasingly important to society as new professions emerge as a result of technology advancements, especially in Information Technology and Data Sciences. It is expected that in the near future about 15% of today jobs will disappear: car divers, translators, accountants, health care laboratory workers, some jobs in the legal system and in teaching.

Education today has very little to offer in terms of spatial cognition. This type of knowledge comes mostly from home and self-education: LEGO, Rubik's cube, origami could be considered some initial points in spatial education. That is probably due to the lack of coherent teaching methods and evaluation techniques. Quantitative and analytics skills are well measured in school with tests including IQ, but spatial skills are considered minor. Consequently, education for professions like architect, robotics engineer, surgeon, data visualization programmer and many more could start very late, typically after high school.

The proposed framework of Polyhedral Computing ([AS]) addresses some of the issues mentioned above about spatial cognition, and generates an open-end "playground" for all ages. Polyhedral Computing operates with shapes inspired by the Platonic and Archimedean solids. Regular polyhedra and their truncations are the building blocks of this system.

There are two options of carrying out the generation of complex polyhedral shapes. Humans can interactively conduct the evolutionary design or they can delegate the tasks to computers via simulations. For instance, as soon as the input and the type of operations are specified, the computer will run the simulation one step at-a-time to transform an unorganized collection of polyhedra into a large unique block. The results of such simulations can be interpreted as geometric expressions obtained from geometric elementary modules connected via geometric connecting operations. The design is scale-free, allowing researchers to investigate multiple shapes consisting of modules of various scales: small, large and in between. Such an experiment is illustrated in Section 3, Fig.3.

Polyhedral Computing can be viewed as a special case of Natural Computing Systems ([LKGR]). This platform might be useful for architectural research based on polyhedral shapes, and therefore balancing creativity with harmony.

Several pilot studies showed that secondary school students undergoing training in Polyhedral Computing significantly improve their results in math tests and their performance in learning geometry ([AVV]). Contemporary architects have an important responsibility to finding solutions to design artificial spaces in terms of sustainable design.

This framework could be successfully used in training young architects, as their spatial cognition, spatial intuition and special intelligence will be enhanced via a coherent, systematic, open-ended and creative educational playground. Architects and researchers could use this platform for the discovery of new spatial structures with artistic and/or technological values.

2. Natural computing systems and polyhedral computing

Genetics, computational architecture and digital computers display a series features characteristic for Natural Computing Systems, or NCS, e.g.,

- The system has an infinite set of states described by a (finite or infinite) collections of features.
- The states of the system can be represented in an “one-at-a-time” fashion,
- The system displays a set of operations that allow state transition, from an individual state to a new state, via a “transition” matrix. The transition matrix can be deterministic, as for digital computer systems, or stochastic as for genetic systems.

Here we introduce Polyhedral Computing as the NCS with the states generated from three “atomic” modules, obtained via rectification from Platonic solids ([WW]) having all edges of the same length: tetrahedron (T), octahedron (O) and icosahedron (I) as depicted in Fig.1, by sequentially applying any of the three polyhedral operations as described below in Fig.2.: delta, nabla and gamma operations.

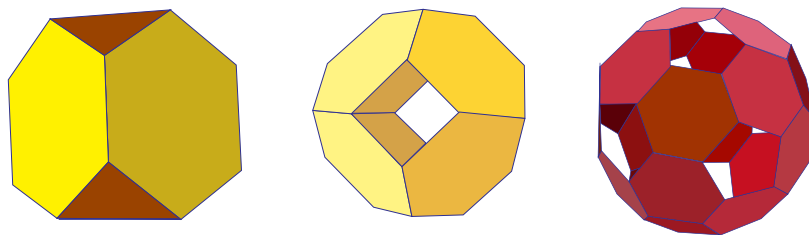


Figure 1. Module T, Module I, Module O.

The modules should be interpreted as having solid faces (regular hexagons) and virtual/empty faces (equilateral triangles, squares or regular pentagons).

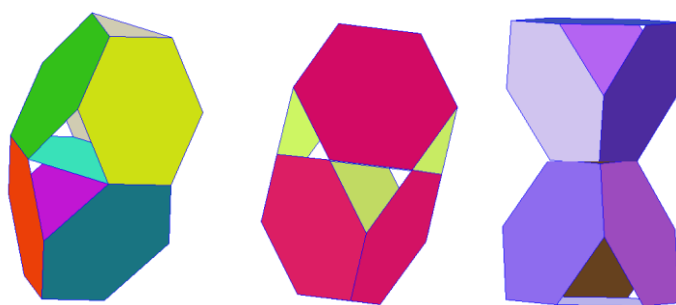


Figure 2. Delta (T,T), Gamma (T,T), Nabla (T,T).

The system can generate expressions by applying iteratively the connection operations to a set of modules. Some of the expressions will be valid, while others will be invalid, depending on their spatial representability. By adding as semantics the spatial representability in Euclidean space, Polyhedral Computing becomes an NCS.

3. Geometric expressions

Geometric expressions generated by Polyhedral Computing can be complex as they are combinatorial in nature, as shown in Fig. 3.

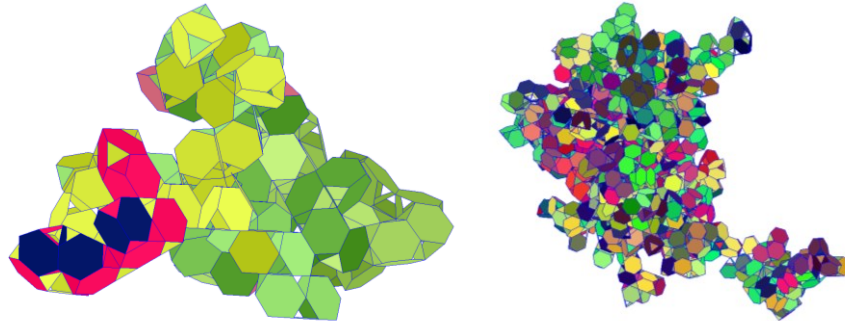


Figure 3. 100T modules, 1000 modules.

The architecture of Félix Candela fits perfectly with this workflow, as he designed an initial constructive system, and applied multiple variations to it. The figures 5 and 6 shows the variations of the inverted umbrella adapted to different projects.

4. Connections between Polyhedral Computing and architecture

A historical review ([FK], [FML]) of the architectural icon's in terms of spatial volumetric and structural revolutions ([RBF]), reveals profound connection between architecture and mathematics. These approaches use regular polyhedra ([LZ]) at various scales, in terms of spatial volumetric expressions ([DC]), as basic cells of their structural system ([HSFKSTBP]). Moreover, the vision of the future presented in ([JC]) is revealed as *Platonic World*.

Today's spatial research in architecture is in its infancy as implied by Toyo Ito's *Architecture Museum* in Imabari, Japan, built in 2011.

5. Conclusions

Polyhedral Computing is able to become a complex instrument for developing spatial intelligence, educational programs and architectural research.



Figure 4.

This proposed spatial cognition framework offers new tools for spatial research and education, with a focus on applications to architecture:

- allows scale-free analysis and investigation of spatial structures,
- utilizes a finite number of polyhedra and a finite number of connectivity operations iteratively,
- it resembles the living cell at metaphoric and physical level, as part of the newly created artificial space,
- it encapsulates the essence of creativeness,
- it inherits its harmony from the perfectness and harmony of the Platonic and Archimedean solids,
- it leads to cost-efficient solutions from the point of view of materials, transportation, deployment and reusability.

The architects became, more often today, when the speed of life increases exponentially, highly aware intellectuals, citizens and artists. Their mission is to create the artificial environment where the harmony between technology and life is achieved and maintained perpetuum.

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Biography

Flavia Maria Rosu. Ph.D., lecturer architect, (October 11, 1969, Brad, Romania) holds a current position as associate professor at the Synthesis of Architectural Design Department, "Ion Mincu" University of Architecture and Urbanism, Bucharest, Romania. She is also the founder of RFM&V Individual Architectural Office. Her passion for architecture and education lead her to focus on architectural competitions and she won several awards at national competitions since she was a student. Following the conclusions of her Ph.D. thesis, her new vision has become that architecture must comply with the Fundamental Laws of Universe and Life. Consequently, her interest focused on experimental architectural education, and she expanded her daily activities with various workshops for young generations of kids. <http://www.anuala.ro/proiecte/2016/223/> She is also very fond of interdisciplinary research, that will allow architecture to benefit from knowledge in other sciences and conversely. In this respect, Flavia incites you to fruitful collaborations. via_fl@yahoo.com.